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Sustainable Building Assessment Tool in Slovakia

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Abstract

In recent years, the evaluation of building performance in terms of environmental, social and economic aspects has become a topic of discussion in the Slovak Republic. A new Building Environmental Assessment System (BEAS) has been developed at the Institute of Environmental Engineering, Technical University of Košice. The main fields and indicators of BEAS are proposed on the base of available information analysis from particular fields and also on the base of our experimental experiences. The proposed indicators respect Slovak standards and rules. Percentage weight of fields and indicators are determined on the basic their significance, according to multi-criteria decision analysis.

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*Keywords:*building environmental assessment; sustainable buildings; AHP method; system; method

Nomenclature

BEAS	Building Environmental Assessment System
GWP	Global-warming potential
AP	Acidification potential
HVAC	Heating, Ventilating, and Air Conditioning systems
AHP	Analytical Hierarchy Process
MAD	Median Absolute Deviation

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1. Introduction

Sustainability assessment of buildings is becoming necessary for sustainable development. The main goals of sustainable design is to reduce depletion of critical resources like energy, water, and raw materials; prevent environmental degradation caused by facilities and infrastructure throughout their life cycle; and create built environments that are safe and productive [1]. Methods and systems for integrated evaluation of buildings are used for the purpose of pre-design, design, construction, operation, maintenance and end of life of sustainable buildings [2]. According to ISO 15392 (2008), construction sustainability includes' considering sustainable development in terms of its three primary aspects (economic, environmental and social), while meeting the requirements for technical and functional performance' [3, 4]. The criteria of sustainability are included in building environmental assessment systems and tools used in different countries for evaluating their sustainable and environmental performance. According to study [5], sustainable building is a multidimensional concept; attention to the issue often focuses solely on environmental indicators, ignoring the substantial importance of social, economic and cultural indicators. Building sustainability involves various relations between built, natural and social systems and therefore comprises a complex of different priorities that require consideration at each stage of a building's life-cycle. Study of Ding [6] states that the comprehensive assessment of buildings is very important in achieving sustainable development. The aim of the building environmental assessment is to provide a sustainable building design, construction, operation, maintenance and renovation which require cooperation between civil engineers, architects, designers, environmentalists and other experts from different areas of building performance. Sustainable buildings involve taking the entire life cycle of buildings, taking environmental quality, functional quality, social and cultural factors, economic factors as well as future values into account [6]. The building construction industry consumes a large amount of resources and energy and, owing to current global population growth trends; this situation is projected to deteriorate in the near future. Climate change became a priority issue on the agenda of the energy and environmental policy of the European Union. Energy efficiency and renewable energy are the main pillars to cope with climate change [7]. Buildings consume approximately 40 % of total global energy: during the construction phase in the form of embodied energy and during the operation phase as operating energy [8-12] and 36 % of total CO_2 emissions of the EU Member States [10, 13]. Recognition of the role of anthropogenic carbon dioxides impact on climate change in recent years has led to the need for worldwide commitments in reducing carbon dioxide and other greenhouse gases [14]. The goal of this paper is to present proposal of building environmental assessment system BEAS applicable in condition of Slovak Republic and significance weighting determination of proposed indicators. Percentage weight of significance is determined according to methods of multi-criteria decision analysis (MCDA). The results of presented field of environmental assessment system are verified on selected residential buildings. The development of assessment methods and the respective tools is a challenge both for the academia and in practice. An issue of prime importance is that of managing the flows of information and knowledge between the various levels of indicator systems. An important constraint to these methods is that the specific definition of the terms "sustainable building" or "high performance building" is complex, since different actors in the building's life-cycle have different interests and requirements [15]. For instance, promoters will give more attention to economic issues, whereas the end users are more interested in health and comfort issues [1]. In assessing the performance of buildings, the scope of environmental evaluation is widening, marking an evolution from a single criterion consideration, like the economic performance of buildings, towards a full integration of all aspects emerging during the lifetime of a building and its elements. It becomes therefore clear, that "Sustainable Buildings" is a broad, multi-criteria subject related to three basic interlinked parameters: economics, environmental issues, and social parameters [16]. Also, modern buildings and their Heating, Ventilating, and Air Conditioning systems (HVCA) are nowadays required not only to be more energy efficient while adhering to an ever-increasing demand for better performance in terms of comfort, but equally in respect to financial and environmental issues [17-19]. Many methodologies have been developed to establish the degree of accomplishment of environmental goals, guiding the planning and design processes. In these earlier stages of the construction process, planners can make decisions to improve building performance at very little or no cost, following the recommendations of the decision-making tool. The development of building environmental assessment is enhanced for last twenty years over the world. Studies states [5, 20] that the BREEAM was modified for Lithuanian recreational buildings assessment and SBTool was modified for Portuguese exist, new and renovated residential building. The amount of information and tools are available to assist designers and builders in incorporating sustainable technologies and design strategies in their projects. In relation to existing tools, many reports [21] present a description of the characteristics of a number of evaluation tools which are used for building and building materials, nationally and internationally. Building environmental assessment systems aim at considering the three aspects of sustainability of buildings: environmental issues such as greenhouse gas emission and energy consumption, economic aspects such as investment and equity and social requirements such as accessibility and quality of spaces. The most common building environmental assessment systems are the multi-criterion systems. Multi-criterion systems base the evaluation on criteria measured by several parameters, and compare real performances with reference ones. Each criterion has a certain number of available points over total assessment and the overall evaluation of sustainability comes out by summing the results of assessed criteria [3]. BEAS as a multi-criteria system which is incorporated in proposed main fields: site selection & project planning; building construction; indoor environment; energy performance; water management and waste management. This paper deals with the proposal of a building environmental assessment system and weighting of indicators in system BEAS.

2. Methodology

The purpose of this paper is to introduce the building environmental assessment system (BEAS), which has been developed at the Technical University of Košice. The Slovak system has been developed on the basis of existing systems used in many countries. The BEAS covers number of environmental, social and cultural factors. Proposed indicators respect Slovak standards and rules. On the base of study of existing system for building environmental assessment was proposed framework of system BEAS. The indicators were proposed according to available information analysis from particular fields of building performance as well as on the base of own experimental experiences. Percentage weights of fields and indicators are determined on the basis their significance, according to multi-criteria decision analysis. The proposal of the main fields results from the quality of the outdoor and indoor environment, nature and landscape conservation, exploitation of natural resources and so on. Building construction is subject to environmental deterioration, hence the proposal of site selection and project planning field is valid in BEAS. In Slovakia, buildings are characterized by high energy consumption therefore the energy performance is also an important field of assessment. Energy performance related to indoor environment of buildings. The buildings are more energy efficient; the more compromised the quality of their indoor environment. Selection of building materials and structures is very important in term of embodied energy and emissions of pollutants. Next very important fields are water and waste management. After fields and indicators were proposed, they were weighted using the AHP method. The methodology of the derivation of assessment field in BEAS has been performed according to a study [22]. A field list has been derived by a three-step process. In order to establish a comprehensive set of fields of the building environmental assessment method for residential buildings, a combination of reviewing existing methods of building environmental assessment used worldwide, valid Slovak standards and codes, and an academic research paper has been conducted. A three-step process has been conducted below. First step was based on reviewing the existing building environmental assessment systems and indicators have been collected. The amount of information and tools are available to assist designers and builders in incorporating sustainable technologies and design strategies in their projects. In relation to existing tools, many reports [21, 24] present a description of the characteristics for a number of evaluation tools which are used for building and materials, nationally and internationally. Second step was based on a selection of a draft field list from the full field list based on in-depth analysis. Final main assessment fields and indicators in BEAS are shown in the Table 1. As a result, a final list of fields has been proposed. The multi-criteria framework incorporates the consideration of environmental issues in a development and it will play an important role in the evaluation approach. To ensure that the indicators developed are applicable to the operations of the business it is necessary to verify and revise the indicators through fieldwork reviews and consultation with experts and stakeholders. This series of verification/modification processes is repeated until a refined set of indicators is obtained that is both necessary and sufficient to monitor the sustainability performance of buildings [25]. In step 3, a questionnaire survey has been conducted in order to get the comment from the group of participating experts to refine the draft fields. A questionnaire survey which aims to weight the final fields in BEAS has been conducted with the 10 experts. Their task was the determination of significance intensity of main fields according nine-point scale of relative importance [26]. Complete criterion significance weighting was determined by using of Median Absolute Deviation (MAD) method was used. MAD is well known statistical method that is mostly used in problem of decision between many independent opinions.

Table 1-Proposed field, sub-fields and indicators in BEAS.

A Site Selection and Project Planning	A1Site selection	A1.1 Use of land with previously high ecological sensitivity or value; A1.2 Land vulnerable to flooding; A1.3 Land close to water endangered contamination; A1.4 Distance to commercial and cultural facilities; A1.5 Distance to public green space; A1.6 Distance to road-traffic infrastructure
	A2 Site development	A2.1 Development of density; A2.2 Possibility of change of building purpose; A2.3 Impact of the design on existing streetscapes; A2.4 Compatibility of urban design with local cultural values; A2.5 Policies governing use of private vehicles; A2.6 Guarantee of sufficient public green space; A2.7 Provision of trees whit shading potential
B Building Construction	B1 Materials	B1.1 Degree of re-use of suitable existing structures where available; B1.2 Use of materials that are locally produced; B1.3 Material efficiency of structural and building envelope components; B1.4 Radioactivity of building materials; B1.5 Ease of disassembly, re-use or recycling
	B2 LCA	B2.1 Primary energy embodied in building materials; B2.2 GWP; B2.3 AP
C Indoor Environment		C1 Thermal comfort; C2 Humidity; C3 Acoustic; C4 Daylighting; C5 TVOC; C6 Indoor air quality; C7 Radon; C8 NOx; C9 PM10; C10 Microbe
D Energy Performance	D1 Operational Energy	D1.1 Energy consumption for heating; D1.2 Energy consumption for domestic hot water; D1.3 Energy consumption for mechanical ventilation and D1.4 Energy consumption for cooling; D1.5 Energy consumption for lighting; D1.6 Energy consumption for appliances
	D2 Active systems using renewable energy sources	D2.1 Solar system; D2.2 Heat pump; D2.3 Photovoltaic technology; D2.4 Heat recuperation
	D3 Energy Management	D3.1 Energy management system; D3.2 Operation and maintenance; D3.3 Degree of local control of lighting systems; D3.4 Degree of personal control of technical systems by occupants
E Water Management		E1 Reduction and regulation of water flow; E2 Surface water run-off; E3 Drinking water supply; E4 Using filtration “grey water”
F Waste Management		F1 Measures to minimize waste resulting from building operation; F2 Measures to minimize emission resulting from building construction, operations and demolition ; F3 Risk of hazardous waste resulting from facility operations

According to Lee et al. [27] credit-weighting is the heart of all assessment schemes since it will dominate the overall performance score of the building being assessed. However, there is at present neither a consensus-based approach nor a satisfactory method to guide the assignment of weightings. The aim of this paper is also assessment of selected residential buildings situated in the east of Slovakia. For the evaluation were selected traditional new building houses. These houses were built of traditional non-renewable materials such as brick, concrete etc. which are traditionally used in Slovakia. Ten residential buildings according to available documentations, mainly drawings were assessed.

3. Results and Discussion

Criterion significance weighting was determined by using of Median Absolute Deviation. One solution how to obtain a weighting of criterions that is acceptable to as large subgroup of experts as it is possible is median absolute deviation method. It is obvious that arithmetical average is not suitable solution for such set of data. Arithmetical average should largely change an opinion of larger group of experts just because of different opinion of one expert. Expert preferences were expressed by 9 to 1 point scale according to Saaty method [28]. We have chosen the median absolute deviation method because the method is able to cope with above defined problem. Result of such method is in the Table 3. There are shown the percentage weightings of main fields in system BEAS determined on the base of expert preferences expressed the significance of proposed assessment fields. The result is obtained from evaluation of each building according to proposed system BEAS in six main assessments filed and 52 indicator of assessment. The principle of indicator evaluation is theoretically the same. Each main field has several indicators of assessment which take the intent of assessment and the scale of assessment into consideration. This scale is from negative (-1 point), acceptable practice (0 point), good practice (3 point) and best practice (5 point). The results of each indicator assessment are obtained so that the point from the scale is multiplied by weight of the indicator according to their significance determined by expert's panel. The total average weighted buildings score is 1.47 point from scale -1 to 5 point which is classified as "Environmentally acceptable buildings". The worst result achieved building construction field and the best result achieved indoor environment filed. The results it can assert, that it is necessary to propose measures to improve the environmental suitability, safety and reliability in all assessed fields.

Table 3.Results of expert identification of significance of main assessment fields.

Criterion	A	B	C	D	E	F
Weights [%]	26.60	21.82	25.23	19.68	5.99	0.68

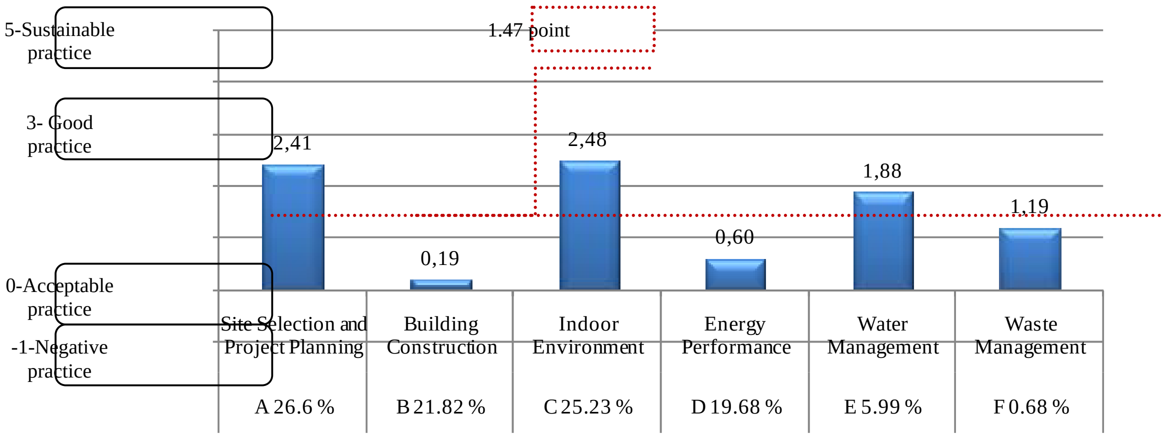

Fig. 1. Average result of environmental assessment of ten selected residential buildings.

Many studies are dealing with the assessment of residential buildings. LEED application of evaluation to an Italian existing building deals study [29]. In the study [30], LEED for Homes (LEED-H) rating method was tested on three existing Malaysian green homes. Study [20] presented modified BREEAM model reveals three sustainable development principles in the development of the buildings was proposed for assessing the sustainability of Lithuania buildings in future. Study of Seinre [31] is focused on building sustainability objective assessment in Estonian context and a comparative evaluation with systems LEED and BREEAM. Study [5] introduces developing the methodology SBTool^{PT}-H for sustainability assessment and rating of existing, new and renovated residential building in Portugal. Studies [32] introduced developing sustainable residential buildings in Saudi Arabia. Methodology of system BEAS is intended to increase the sustainable residential buildings design, construction, operation and maintenance in Slovakia.

Conclusion

System BEAS was inspired by system used in the world with have a respect with national standard, law and concisions in Slovak republic. The purpose of this paper was introduced the development of building environmental assessment system in Slovakia. Secondly, study aimed at determination of significance weights of main field of assessment and evaluation of residential buildings. Each main field in system BEAS has several indicators which have the intent of assessment and the scale of assessment. Methodology of system BEAS is intended to increase the sustainable residential buildings design, construction, operation and maintenance in Slovakia. On the base of intensity expression of significance has been assigned the order of fields. The identification of significance of main assessment fields has been determined by experts. The final weights have been determined using MCA. Results of determination are: A-27.30%, B-18.43 %, C-27.30 %, D-20.30 %, E-5.99% and F-0.68%. Result of evaluation of ten residential building is 1.47 points form 5 point scale. The different building environmental assessment tools do however require varying amounts of data for their assessment. The system and methods of impact rate classification are also different and mostly respect their national conditions and requirements.

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